Design of Sheet Pile Walls

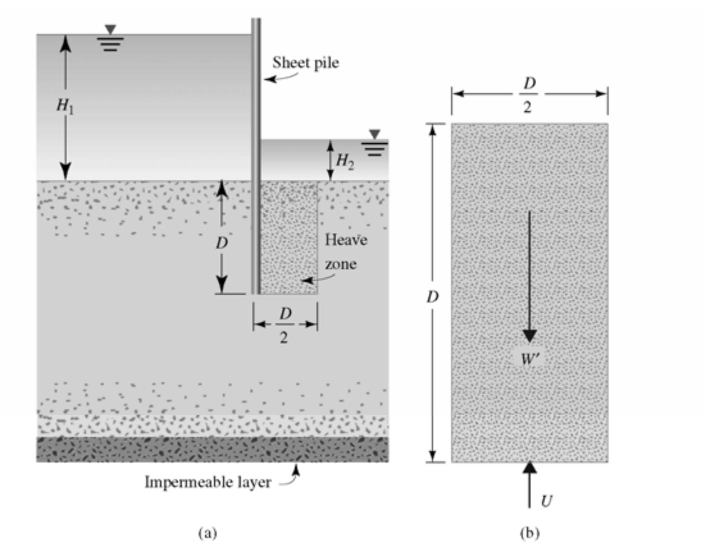

Figure 6.8 (a) Check for heaving on the downstream side for a row of sheet piles driven into a permeable layer; (b) enlargement of heave zone

Conditions Adjacent to Sheet Piling

High upward hydraulic gradients may be experienced in the soil adjacent to the downstream face of a sheet pile wall. Fig. 3.7 shows part of the flow net for seepage under a sheet pile wall, the embedded length on the downstream side being d. A mass of soil adjacent to the piling may become unstable and be unable to support the wall. Terzaghi has shown that failure is likely to occur within a soil mass of approximate dimensions $d \times d/2$ in section (ABCD in Fig. 3.7). Failure first shows in the form of a rise or *heave* at the surface, associated with an expansion of the soil which results in an increase in permeability. This in turn leads to increased flow, surface 'boiling' in the case of sands, and complete failure.

The variation of total head on the lower boundary CD of the soil mass can be obtained from the flow net equipotentials but for purposes of analysis it is sufficient to determine the average total head h_m by inspection. The total head on the upper boundary AB is zero.

The average hydraulic gradient is given by

$$i_m = \frac{h_m}{d}$$

Since failure due to heaving may be expected when the hydraulic gradient becomes i_c, the factor of safety (F) against heaving may be expressed as

$$F = \frac{i_c}{i_m} \tag{3.9}$$

In the case of sands, a factor of safety can also be obtained with respect to 'boiling' at the surface. The *exit* hydraulic gradient (i_e) can be determined by measuring the dimension Δs of the flow net field AEFG adjacent to the piling:

$$i_e = \frac{\Delta h}{\Delta s}$$

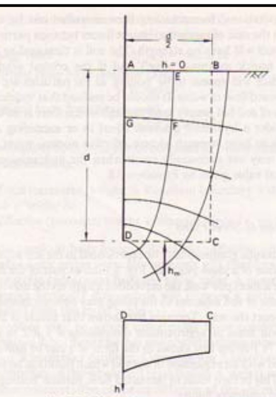

Fig. 3.7 Upward seepage adjacent to sheet piling.

where Δh is the drop in total head between equipotentials GF and AE. Then the factor of safety is:

$$F = \frac{i_c}{i_e} \tag{3.10}$$

There is unlikely to be any appreciable difference between the values of F given by Equations 3.9 and 3.10.

The sheet pile wall problem shown in Fig. 3.7 can also be used to illustrate the two methods of combining gravitational and water forces.

1. Total weight of mass ABCD $= \frac{1}{2}\gamma_{sat}d^2$

   Average total head on CD $= h_m$

   Elevation head on CD $= -d$

   Average pore water pressure on CD $= (h_m + d)\gamma_w$

   Boundary water force on CD $= \frac{d}{2}(h_m + d)\gamma_w$

Resultant body force of ABCD $= \frac{1}{2}\gamma_{sat} d^2 - \frac{d}{2}(h_m + d)\gamma_w$

$$= \tfrac{1}{2}(\gamma' + \gamma_w)d^2 - \tfrac{1}{2}(h_m d + d^2)\gamma_w$$
$$= \tfrac{1}{2}\gamma' d^2 - \tfrac{1}{2}h_m \gamma_w d$$

2. Effective weight of mass ABCD $= \frac{1}{2}\gamma' d^2$

   Average hydraulic gradient through ABCD $= \dfrac{h_m}{d}$

   Seepage force on ABCD $= \dfrac{h_m}{d}\gamma_w \dfrac{d^2}{2}$

   $= \frac{1}{2}h_m \gamma_w d$

   Resultant body force of ABCD $= \frac{1}{2}\gamma' d^2 - \frac{1}{2}h_m \gamma_w d$ as in method 1 above.

The resultant body force will be zero, leading to heaving, when:

$$\tfrac{1}{2}h_m \gamma_w d = \tfrac{1}{2}\gamma' d^2$$

The factor of safety can then be expressed as

$$F = \frac{\frac{1}{2}\gamma' d^2}{\frac{1}{2}h_m \gamma_w d} = \frac{\gamma' d}{h_m \gamma_w} = \frac{i_c}{i_m}$$

If the factor of safety against heaving is considered inadequate, the embedded length *d* may be increased or a surcharge load in the form of a filter may be placed on the surface AB, the filter being designed to prevent entry of soil particles, If the effective weight of the filter per unit area is w' then the factor of safety becomes

$$F = \frac{\gamma' d + w'}{h_m \gamma_w}$$

Example 3.3

The flow net for seepage under a sheet pile wall is shown in Fig. 3.8a, the saturated unit weight of the soil being 20 kN/m³. Determine the values of effective vertical stress at A and B.

1. First consider the combination of total weight and resultant boundary water force. Consider the column of saturated soil of *unit area* between A and the soil surface at D. The total weight of the column is $11\gamma_{sat}$ (220 kN). Due to the change in level of the equipotentials across the column, the boundary water forces on the sides of the column will not be equal although in this case the difference will be small. There is thus a net horizontal boundary water force on the column. However, as the effective *vertical*

Example

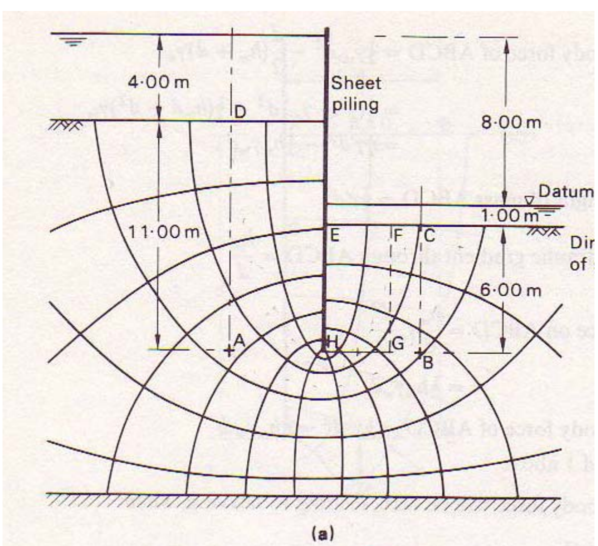

Fig. 3.8

$$\gamma_{sat} = 20kN/m^3$$

Factor of Safety Against Quick Condition

$$N_d = 12 @ h_m \; n_d = 3.5$$

$$h_m = h\frac{n_d}{N_d} = 8.0m * \frac{3.5}{12} = 2.3m$$

$$d = 11m$$

$$i_m = \frac{h_m}{d} = \frac{2.3}{6} = 0.39$$

$$i_c = \frac{\gamma'}{\gamma_w} = \frac{20kN/m^3 - 9.81kN/m^3}{9.81kN/m^3} = 1.04$$

$$FS = \frac{i_c}{i_m} = \frac{1.04}{0.39} = 2.7$$

Effective Stress @ A

$$\sigma_A = 11m * 20kN/m^3 + 4m * 9.81kN/m^3 = 259kN/m^2$$

$$h_A = 8m\frac{8.2}{12} = 5.5m$$

$$h_A = h_e + h_p$$

$$h_p = h_A - h_e = 5.5m - (-7m) = 12.5m$$

$$u_A = 16.5m * 9.81 = 122kN/m^2$$

$$\sigma'_A = \sigma_A - u_A = 259 - 122 = 137kPa$$

Effective Stress @ B

$$\sigma_B = 6m * 20kN/m^3 + 1m * 9.81kN/m^3 = 130kN/m^2$$

$$h_B = 8m\frac{2.5}{12} = 1.67m$$

$$h_B = h_e + h_p$$

$$h_p = h_B - h_e = 1.67m - (-7m) = 8.7m$$

$$u_B = 8.7m * 9.81 = 85.3kN/m^2$$

$$\sigma'_B = \sigma_B - u_B = 130 - 85.3 = 44.7kPa$$